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Hailing the hybrid

Professor Franck Dumeignil, EuroBioRef Coordinator at the Université Lille Nord de France, turns the spotlight onto a new golden age of catalysis…

To date, catalysis has strongly backed the development of the fossil resource-based chemical industry, eg for upgrading oil cuts (hydrotreatments, cracking reactions, etc) and efficiently valorising molecules to chemicals. Nowadays, 95% of all products (in volume) of the chemical industry are synthesised using at least one catalytic formulation. More than 70% of the total industrial chemical processes involve catalysts, which can be heterogeneous (80% of the total catalytic processes), homogeneous (15%), or enzymatic (5%). More than 80% of the added value of the chemical industry is generated by catalysis. The associated catalytic processes are now mature and most of the work on chemical valorisation of petro-resources consists of the optimisation of existing processes and catalytic formulations.

Since the beginning of this century, the development of catalysts has encountered a new boom, with an exponential growth of scientific articles dealing with the catalytic conversion of biomass and the upgrading of biomass-derived platform molecules. With the progressive rarefaction of fossil resources, biomass is indeed driving much interest. Catalysis is a key technology at the core of the biorefineries development, for example, in the novel EuroBioRef concept in which catalytic reactions are envisaged in sequential processes, consisting of homogeneous, heterogeneous and enzymatic catalysis, optionally interweaved with thermochemical reactions.

In this context, catalysis faces new challenges. For example, biomass-derived molecules are highly functionalised, and, thus, very selective catalysts must be developed. Further, biomass-derived molecules are much more reactive than the petroleum-derived ones, which could be seen as an advantage, but which leads to much faster coking issues that need to be properly addressed. In addition, the presence of water in most of the streams has an influence on the surface properties of the catalysts. Their in situ functions are most probably different from those that can be deduced from conventional ex situ analysis. Accordingly, new specific characterisation technologies must be developed that take into account the presence of water in the working atmosphere for gas phase reactions. The liquid aqueous phase operando methodologies can also be envisioned. Finally, the presence in the real feeds of various impurities inherent to biomass upstream treatments induces the need to rethink the catalytic formulations in order to ensure sufficient tolerance to these new kinds of performance-killing compounds. Thus, a large number of strategies must be applied to design a new generation of smart heterogeneous catalysts for biomass processing technologies.

The next step will undoubtedly be to combine in a one pot process the biotech and heterogeneous catalysts. These two worlds already coexist as sequential reactions in some processes, but full integration is now a topical interest. They can be gathered only using overlapping areas of conditions, eg temperature, and the potential area of common temperatures has strongly expanded due to progress in both fields. First, enzymes that can work in a larger temperature range, from low temperatures (eg psychrophilic enzymes, discovered in the Antarctic, can work at temperatures as low as 0°C, and are currently used in washing powders/liquids so that they are efficient even in cold water) to high temperatures (thermophilic and hyperthermophilic enzymes, discovered in deep-sea hydrothermal vents, can still work at temperatures as high as circa 110°C). Some heterogeneous catalysts are adapted to this range of temperatures, for example, gold-based catalysts can, in certain cases, develop strong activity from temperatures well below 0°C. Therefore, the interval between 0°C and 110°C can be used. Temperature is only one example and a set of other common processing areas can be identified.

The smart integration of these technologies requires the development of new concepts. Their variety depends on scientists' imagination and the next decade will undoubtedly see the emergence of fully 'hybrid' catalytic systems.

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